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Death and Deterioration of Balsam Fir Weakened by Spruce Budworm Defoliation in Ontario[1]

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Part I Notes on the seasonal history and habits of insects breeding in severely weakened and dead trees[1]

One of the problems arising from severe outbreaks of the spruce budworm, *Choristoneura fumiferana* (Clem.), is the evaluation of the factors contributing to the decline of the host trees. An intensive study of the death and deterioration of balsam fir, *Abies balsamea* (L.) Mill., was carried out from 1946 to 1951 in the area southwest of Lake Nipigon in northwestern Ontario, where a severe spruce budworm outbreak was in progress.

This paper is the first of three presenting results of the study, and deals with the seasonal history and habits of the insect species which breed in severely defoliated and dead balsam-fir trees. Subsequent papers of the series will deal with the part played by these insects in the death of weakened balsam-fir trees, and the entomological and pathological deterioration of the trees after death.

The following bark- and wood-inhabiting insects were found breeding in dying and newly-dead trees:

Order COLEOPTERA
Family Cerambycidae
Monochamus scutellatus Say—the white-spotted sawyer beetle
Monochamus marmorator Kby.—the balsam sawyer beetle
Tetropium cinnamopterum Kby.—the four-eyed spruce borer
Family Curculionidae
Pissodes dubius Rand.—the balsam weevil
Family Scolytidae
Pityokteines sparsus Lec.—the balsam bark beetle
Trypodendron bivittatum Kby.—the spruce ambrosia beetle
Family Melandryidae
Serropalpus substriatus Hald.
Order HYMENOPTERA
Family Siricidae
Sirex cyaneus F.
Sirex sp. (*noctilio* group)
Urocerus albicornis F.

Some of the species were scarce in the study area, and their seasonal history and habits could not be studied as intensively as for the more abundant insects. Moreover, some species were not involved in the death of weakened trees, for they attacked only trees that were obviously dead. Emphasis was placed on those species that might have contributed to tree death.

The details of seasonal history and habits have been assembled from several sources. Throughout the study, marked trees were described at weekly intervals

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and the trunk was closely examined for evidence of insect attack. When attacks were found, insect development was followed by removing small pieces of bark from the host tree. When heavy attack by a particular species was noted, examinations were made at two- or three-day intervals to obtain more detailed information. These field examinations were supplemented by cage studies of logs from trees attacked by different species at known times. Periodically throughout the study, infested trees were felled, and representative samples of the trunk were carefully examined to determine the distribution of the insects in the host tree.

Pityokteines sparsus Lec.

This bark beetle was found more frequently than any other insect species. Practically all trees dying after severe spruce budworm defoliation were heavily infested by it. Only brief accounts of its seasonal history and habits have been published (2, 4, 6, 9, 10). The seasonal history in the study area, already reported in abbreviated form (1), is presented in Fig. 1. The diagram encompasses a period of one complete year. Horizontal lines illustrate the duration of each developmental period and arrows illustrate the sequence of events. Lines labelled "attack" signify the periods during which the adult beetles enter the host tree and establish nuptial chambers and brood galleries in preparation for egg laying.

After laying the eggs of the first brood in June, some of the parent adults that make the earliest attacks of the season (upper left of diagram) emerge from the host tree, attack fresh trees, and establish a second brood. These adults then die in the brood galleries.

The first brood completes development before winter, and the newly-formed adult beetles overwinter. Many adults, particularly those maturing late in the season, remain in the original brood trees, from which they emerge the following spring. The remaining adults emerge from the brood trees in the late

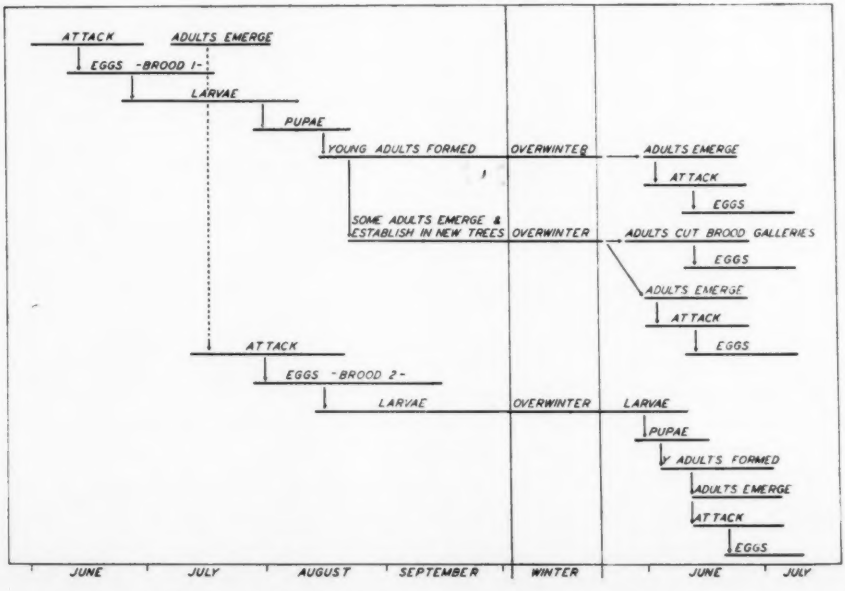


Fig. 1 Representation of seasonal history of *Pityokteines sparsus* Lec.

summer or autumn and establish irregular feeding galleries in newly-dead trees, in which they overwinter. The following spring, most of them emerge and attack uninfested trees, but some may remain in the trees in which they overwintered and establish a brood, if the bark and sapwood are sufficiently moist.

The second brood, being established later in the season than the first, reaches only the larval stage before winter. These larvae are usually full-grown and they overwinter in the larval mines and pupate the following spring. The newly-formed adults of the second brood emerge shortly after overwintering adults of the first brood, and immediately attack suitable uninfested trees. Although adults of the second brood emerge later than those of the first, the two emergence periods overlap. Consequently, only one period of emergence is recognizable in the field, and attacking adults from the first and second broods of the previous year become mixed in the same host trees.

Numerically, the second brood is considerably smaller than the first, because many of the parent adults do not emerge from the host trees after establishing the first brood.

The mining habits of both adults and larvae of *P. sparsus* are very distinctive. The male beetle attacks the host tree first, boring through the bark to the surface of the wood where it cuts a nuptial chamber. The entrance tunnel is approximately 0.03 inches in diameter, and is invariably slanted upwards from the bark surface. The entrance hole in the bark is circular and is easily recognized by a small pile of very fine boring dust spilled out of the tunnel while the adults are actively mining. The nuptial chamber itself is of irregular shape, usually not more than one-quarter of an inch across, and is cut almost equally in the outer sapwood and inner bark. When the nuptial chamber is complete, the male is joined by from one to four, or occasionally five, females. Each female mates with the male and proceeds to cut its own brood gallery radiating from the nuptial chamber. The average number of brood galleries, based on 358 attacks, was 2.8 $\pm$ 0.1. The brood galleries, like the nuptial chamber, are cut into both outer sapwood and inner bark, and tend to encircle the tree. They extend from 1 to 2 inches from the nuptial chamber. The mean length of brood gallery, based on 1,003 completed galleries, was 1.32 $\pm$ 0.02 inches.

Along one or both sides of the brood gallery, the female cuts small niches in which milky-white eggs are deposited. Each egg is packed into its niche with fine boring dust. The niches are cut and the eggs are deposited as the females progress, so that the first eggs are close to the nuptial chamber (Fig. 2).

The eggs hatch after 12 to 14 days, and the young larvae mine at right angles to the brood galleries, both up and down the tree. The larval mines, which gradually increase in diameter as the larvae develop, are almost entirely in the inner bark; the wood surface is rarely scored until the larvae are nearly full-grown. The larvae extend their mines for 2 or 3 inches from the brood galleries, and destroy a large proportion of the inner bark in heavily infested trees.

Towards the end of July, the larvae are full-grown and pupate in one of three locations. Some larvae merely construct small pupal cells on the wood surface at the end of the larval mine; others mine into the sapwood to a depth of about 0.04 inches and construct pupal cells completely within the wood (Fig. 3). The presence of this type of pupal cell, which has also been described for a European form, *P. curvidens* Germ. (8), is revealed on the wood surface by a small round entrance hole (Fig. 4). Still other larvae mine outwards and

construct cells completely in the bark (Fig. 5); this type of cell has also been described for *P. curvidens* (8).

The pupal period lasts approximately 12 days, and the newly-formed young adults usually feed for a few days in the inner bark before leaving the host tree through circular emergence holes in the bark. Emergence holes are easily distinguished from entrance holes since they do not slant, but are cut at right angles to the bark surface.

P. sparsus shows no preference for any particular part of the host tree. Eight heavily infested trees were cut during 1949, and bole samples 2 feet in length were taken from basal, middle, and top portions of each tree. The number of bark beetle attacks on each quadrant (north, east, south, and west) of each sample were counted and densities per square foot of wood surface were calculated. Analysis of variance treatment of these data failed to establish a significant difference in density of attack either between quadrants or between levels, indicating random distribution of *P. sparsus* populations throughout the host tree trunk.

Density of infestation is usually high (Fig. 6). A mean density of 36.1 $\pm$ 1.9 attacks per square foot of wood surface was found during the detailed examination of 81.8 square feet of wood surface in the samples referred to above. Densities in individual samples ranged from 2.6 to 83.8 attacks per square foot. Such extensive mining by this insect in the inner bark is largely responsible for the sloughing off of bark so commonly observed in stands of dead balsam fir.

***Monochamus scutellatus* Say**

This wood borer was second in abundance to *P. sparsus* in dying and newly-dead balsam fir trees in the Lake Nipigon area. Swaine *et al.* (10), Graham (6), and Craighead (3) give brief accounts of the seasonal history and habits of this species, or of other representatives of the genus *Monochamus*. Their accounts refer principally to more southern areas where development is usually completed in one year. In the Lake Nipigon area, adult emergence occurs some two to three weeks later than in the more southern regions, commencing in the second or third week of June, depending on the season. Emergence continues until mid-August, but the majority of the adults are in flight by the third week of July. Oviposition in balsam fir commences about July 1 and continues until late August or early September, and the eggs are concentrated, particularly in lightly infested trees, around old branch scars and bark wounds.

Fig. 2. *Pityokteines sparsus*: nuptial chamber and brood galleries, showing parent adult and eggs in niches, early in summer. x 1.

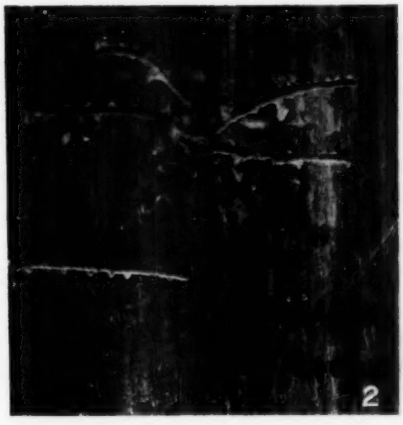
Fig. 3 *Pityokteines sparsus*: longitudinal section through pupal cell in wood. x 14.

Fig. 4. Surface of dead balsam fir tree (x 1) showing: (A) *Pityokteines sparsus*: entrance holes to pupal cells in wood. (B) *Monochamus scutellatus*: wood surface scored by larval mining. (C) *Monochamus scutellatus*: larval entrance hole. (D) *Monochamus scutellatus*: adult exit hole.

Fig. 5. *Pityokteines sparsus*: bark from dead balsam-fir trees with flap of inner bark folded back to show two pupae in bark pupal cells. Note larval mines on inner surface of bark. x 2.

Fig. 6. *Pityokteines sparsus*: block from dead balsam-fir tree with bark folded back (left). to show heavy bark beetle infestation. Note larval mines on inner surface of bark. x $\frac{1}{4}$.

Fig. 7. *Pissodes dubius*: larval mine on surface of dead balsam-fir tree, and pupa in pupal cell at end of mine. x 1.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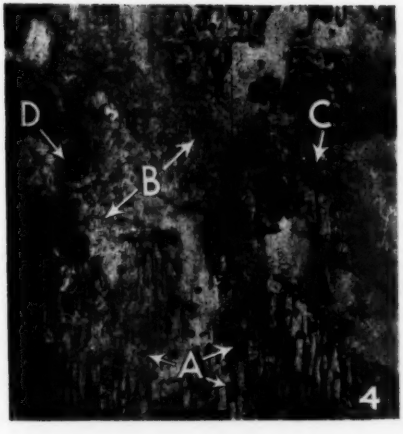
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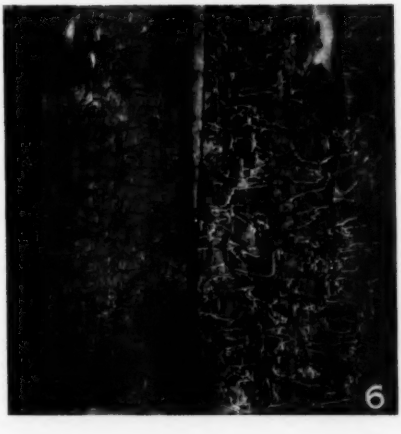
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In the study area, two distinct periods of oviposition in balsam fir are recognized. During July and early August, eggs are laid in recently dead trees, most of which are already infested by *P. sparsus*, and in dying trees previously uninfested. Larvae from these eggs complete their mining between bark and wood before late September and enter the wood, where they overwinter. The following spring, they continue to mine in the wood, complete their tunnels by autumn, and overwinter in the pupal cells just under the wood surface. They pupate in the following spring and the adults emerge during late June and July. A period of approximately 23 months thus elapses between oviposition and adult emergence.

During late July, and throughout August and early September, there is a second period of oviposition, in apparently living trees. These host trees are invariably in an obviously weakened condition but do not succumb until the following winter. Oviposition is always very light, and the eggs are almost always confined to the areas around branch scars and wounds. Little mining between bark and wood takes place before winter, and most of the larvae overwinter between the bark and the wood. In the spring, mining continues on the wood surface, the tree now being obviously dead. The larvae enter the wood in June and complete their tunnels before the second winter, which is spent in the pupal cell. Pupation and adult emergence take place as described. Again, approximately 23 months elapse between oviposition and adult emergence.

Trees attacked during the second period of oviposition are often attacked a second time the summer following death, if the bark and cambium are sufficiently moist. A mixed borer population in the host tree results. Table I illustrates dates of oviposition and adult emergence in three typical trees.

TABLE I

Dates of *M. scutellatus* oviposition and adult emergence in three typical trees at Black Sturgeon Lake

Tree	Oviposition	Adult Emergence
A. (Tree dying at time of attack).....	Mid-July, 1947	1948 — Nil 1949 — June 27 — July 18
B. (Tree died during winter 1947-1948)..	Late August, 1947	1948 — Nil 1949 — June 14-26
C. (Tree died during winter 1946-1947)..	Late August, 1946 Mid-July, 1947	1947 — Nil 1948 — June 8-24 1949 — June 27 — July 15

In trees A and B there was only one period of oviposition, in midsummer and late summer respectively, and in Tree C there were two periods of oviposition which resulted in a mixed borer population.

The distribution of egg and larval populations of *M. scutellatus* throughout the host tree was studied in 1949. Five heavily infested trees were cut for egg distribution studies. The sample consisted of 2-foot blocks from the basal, middle, and top portions of each tree. Since many slits are not utilized in egg laying, the number of empty slits in each quadrant of each sample was recorded as well as the number of eggs. Both counts were then converted to density figures per square foot of bark surface. Analysis of variance treatment of the

data failed to establish a significant difference in density of either empty slits or eggs between different quadrants, but did indicate a significant difference in both measures between levels. The average densities for all five trees are recorded in Table II, in which it is obvious that densities were lower in the top of the tree than in the middle or basal levels, in which they were very similar. Only about 25 per cent of the slits cut by the ovipositing adults contained eggs.

TABLE II

Average densities, per square foot of bark surface, of empty egg slits and eggs of *M. scutellatus* on four quadrants at three levels in five balsam-fir trees, and average density for all samples from all trees.

	Quadrant				Level			Overall average
	N	E	S	W	B	M	T	
Empty slits	23.2	27.7	35.1	24.4	31.5	25.5	15.9	27.6
Eggs	6.9	10.3	9.5	9.7	11.7	12.4	3.4	9.1

Because of the larval mining habits of this species, it is possible to assess population density at various stages in the developmental history of the insect. The young larvae which bore through the bark leave an imprint on the wood surface. The older larvae which enter the wood, and those which complete their development and emerge as adults, can be enumerated by entrance and exit holes in the wood. All three of these measures of population may be taken in the same tree, after adult emergence is complete.

Twelve trees which had been dead for two years or more, and from which all adults had emerged, were analysed. Three 2-foot blocks representing basal, middle and top portions of the tree formed the sample. Analysis of variance treatment of the population data revealed some interesting facts. No significant difference in density between quadrants was established for any of the measures, but a significant difference in density between levels occurred in larval mines on the wood surface and in larval entrance holes, where the density increased with increasing height in the tree (Table III). A trend towards increasing density of exit holes with increasing height was apparent, although statistically the differences were not significant, the average densities being quite low.

TABLE III

Average density per square foot of wood surface for three population measures of *M. scutellatus* on four quadrants at three levels in 12 balsam-fir trees, and average density for all samples from all trees.

	Quadrant				Level			Overall average
	N	E	S	W	B	M	T	
Larval mines on wood surface	9.6	10.3	12.9	11.1	7.2	10.7	14.7	10.9
Larval entrance holes	7.2	8.0	9.4	8.3	5.2	8.1	11.2	8.2
Adult emergence holes	2.5	1.7	3.2	2.3	1.8	2.5	2.9	2.4

A 78 per cent drop in the population occurred between the time the larvae mined on the wood surface and the adults emerged. The greater part of this decline took place after the larvae entered the wood.

All measures indicated that populations of *M. scutellatus* in balsam fir were distributed at random around the tree trunk. Counts indicated lower egg populations in the top of the tree than in the middle or basal portions. Measures of larval and emergent adult populations indicated increasing populations with increasing height in the tree. If these be true measures of population distribution, a differential survival of eggs and newly emerged larvae throughout the length of the tree must be postulated in order to account for the reversal in population weight during the larval mining stage. However, the validity of the egg counts is very doubtful, and such a postulation seems unnecessary. Oviposition by this species was always observed first in the lower part of the tree, and in many cases some of the first-laid eggs had hatched before others had been laid. Therefore, it seems probable that oviposition was not complete when the trees were analyzed, and that late oviposition might be concentrated in the upper part of the trees. Ideally, complete population studies should be carried out in the same trees for all stages of insect development. This was impossible with the methods employed, but might have been done by making egg counts on sections of trees to be left standing for two years or more, and then making counts of larval penetration and adult emergence.

It is concluded, therefore, that populations of *M. scutellatus* are distributed at random around the host tree, and that generally they increase with increasing height in the tree.

Monochamus marmorator Kby.

This species was not as abundant in the Lake Nipigon spruce budworm infestation as in previous infestations elsewhere (10). Few adults were seen or taken in the field, and although Swaine *et al.* (10) report that the beetles are nocturnal, examinations of severely weakened trees for ovipositing adults after dark were unsuccessful. Only in the Chief Bay area close to the original centre of the spruce budworm infestation were adults found on trees or recovered from caged logs.

A detailed account of the seasonal history and habits is given by Swaine *et al.* (10). From very limited observations, the length of life-cycle appears to be the same as that of *M. scutellatus* in the Lake Nipigon area. However, no evidence of two periods of oviposition was found. Logs from two trees at Chief Bay, known to have infested with sawyer beetles during the summer of 1947, were caged in early June, 1948. During the second week of July, 1949, four *M. marmorator* and six *M. scutellatus* adults emerged from one log, and four *M. marmorator* and one *M. scutellatus* adults from the other. The developmental time from egg to adult emergence was therefore approximately 23 months in both species.

Pissodes dubius Rand.

This weevil was a common associate of *P. sparsus* and *M. scutellatus* in both New Brunswick and Quebec (10), and in Minnesota (5, 7), during the severe spruce budworm outbreaks of the early part of this century. In the Lake Nipigon area during this study, however, the species was relatively scarce; less than 20 per cent of all trees examined for trunk-inhabiting insects showed evidence of infestation.

Limited observations suggest some differences in the seasonal history from that summarized by Swaine *et al.* (10). In the Lake Nipigon area, full-grown larvae and pupae were found under the bark of infested trees before the end of June, which indicates that the winter had been passed in the larval stage. Adults emerged from caged logs and from standing trees from the end of June to the middle of August, emerging in greatest numbers during the last three weeks of July. Egg deposition is in punctures made in the bark by the beak of the adult. Eggs are laid in groups in the inner bark, and the larvae, on hatching, bore between the bark and wood both up and down the tree trunk (Fig. 7). Pupation takes place in a cell constructed on the wood surface, and the adults emerge from the host tree through circular holes in the bark. The earliest evidence of adult attack was recorded in a dying tree on August 11, 1947. This tree had been attacked previously by *M. scutellatus* and showed signs of death before eggs and newly-hatched larvae of the weevil were found. Two logs from the tree were caged in early June, 1948, and seven weevil adults emerged between July 13 and July 21 of the same summer. A developmental period of slightly less than 12 months from egg to emergent adult is therefore indicated in the Lake Nipigon area. Swaine *et al.* suggested a two-year life cycle, in which the adults emerged in the late summer but did not oviposit until mid-summer of the following year.

The preference of ovipositing adults of this species for the lower part of the host-tree trunk (10) was confirmed. In 13 of 17 *Pissodes*-infested trees, infestations were confined to the lower fifth of the trunk, and in the remaining four to the lower half. Samples totalling 56.2 square feet of wood surface from portions of study trees showing evidence of infestation contained only 77 individual attacks,[1] a density of 1.4 attacks per square foot.

Trypodendron bivittatum Kby.

Descriptions of the adult galleries and larval development of this ambrosia beetle are available (2, 6), but information on its seasonal history appears to be lacking, except for a very general statement by Swaine *et al.* (10). The species was not common in the Lake Nipigon area. Adults were active early in the season, at about the same time as those of P. *sparsus*. Attacks were observed only during the last week of May and the first three weeks of June, and were confined to trees which had died during the previous winter. Not all trees that died at that time were infested, for those with dry tightly-adhering bark were not attacked. The moisture conditions in the host trees attractive to this species were narrowly defined. Trees moist enough to be attractive to *P. sparsus* were only occasionally infested. Conversely, trees in which heaviest *T. bivittatum* infestations were observed were not infested by *P. sparsus*. Apparently, the ambrosia beetle requires drier conditions than the bark beetle. This narrow preference is probably related to the moisture requirements of the fungus which the adult beetles introduce into their mines and on which the developing larvae feed.

In the few trees in which development was followed throughout the season, pupation took place in early September, and the new adults were formed by mid-September. At the end of September, 1949, in both caged logs and standing trees, adults were found in brood niches in a comatose condition, with a single

[1]An adult oviposition puncture in which eggs have been laid constitutes an individual attack. It can be recognized in a dead tree by following individual groups of larval mines to their common origin.

adult in similar condition blocking the gallery opening, head pointing inwards. In June, 1950, adults emerged from the caged logs. The life cycle was thus completed in one year, with the adults apparently overwintering in the host tree. Swaine *et al.* (10) report that adult emergence takes place immediately after formation of the adults in the late summer. No information is given by those authors on how the winter is passed.

Only 10 per cent of the trees under observation were infested by this species. Most attacks were in the lower part of the trunk and all heavy infestations were confined to the lower quarter. No attacks were observed in the upper half of the tree. The average number of entrances per square foot of bark surface in samples from eight infested trees was 3.8, the highest density in a single sample being 10.0 per square foot.

Tetropium cinnamopterum Kby.

Although reported to be prevalent in dead balsam-fir trees in Quebec and New Brunswick (10), larvae of this species were found in only four trees during this study. All four trees had been dead for some months at the time of examination, and consequently no information was obtained on the seasonal history. No adults were observed on study trees.

Serropalpus substriatus Hald. and the Siricids

The larval mining habits of the melandryid, *S. substriatus*, and of the siricids *Sirex cyaneus* F., *Sirex* sp. (*noctilio* group), and *Urocerus albicornis* F., are very similar, and their mines are difficult to distinguish. These insects attacked only dead trees in the Lake Nipigon area. *S. substriatus* oviposits on, and the siricids just under, the surface of the sapwood. The larval mines seldom penetrate more than 1 inch in the sapwood, and are tightly packed with frass and boring dust behind the developing larvae.

Observations in the field and on caged logs indicated that both *S. substriatus* and the siricids require two years to develop from egg to adult. Adults of all species emerged from study trees and caged logs between mid-July and the end of August. Oviposition was observed from mid-July until mid-September.

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Some Species of Phytophaga (Coleoptera)[1]

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The following notes and descriptions concern the feeding habits, distribution, and other characters of several species and presumed subspecies of Cerambycidae, Chrysomelidae, and Bruchidae.

***Xylotrechus annosus emotus* n. subsp.**

Occurring in British Columbia, Washington, and California; differing from *annosus annosus* (Say) in having the pale areas of the elytra larger and more numerous; the pattern of the elytra therefore much more conspicuous than in *annosus annosus*, which is restricted to regions east of the Rocky Mountains.

Each elytron of *annosus emotus* with poorly delimited yellow markings as follows: a posthumeral spot, this never large and very obscure or entirely lacking in three-fifths of the specimens; a subsutural spot, of variable size but usually small, at basal fourth, this lacking in three of the 61 specimens; a median spot which is virtually sutural, this usually hook-shaped, the longer arm extending along the suture toward or beyond the spot at basal fourth; a sutural spot at apical fourth which usually extends both anteriorly and posteriorly along the suture; two sublateral spots opposite the two sutural spots, the anterior of these very obscure or lacking in five of the specimens.

Holotype.— ♂, Fernie, British Columbia, June 6, 1935 (Hugh Leech), on *Populus trichocarpa* Torr. and Gray; No. 5565 in the Canadian National Collection, Ottawa.

Paratypes.—60, from the following localities in southern British Columbia: Tod Inlet, Sidney, Courtenay, Salmon Arm, Creston, Kelowna, Keremeos, Nicola, Vernon, Midday Valley, Robson, Oliver, Fernie, and Lillooet. The five paratypes from Fernie were taken on *Populus trichocarpa;* most of the 18 from Creston were taken on *P. tremuloides* Michx. or from pupal cells in *P. trichocarpa* by G. Stace Smith. Other localities for *annosus emotus* are Toppenish, Washington, and Buck's Lake, Plumas County, California.

The collection contains 44 specimens taken between Fredericton, New Brunswick, and Sylvan Lake, Alberta, that may be referred to *annosus annosus*, the type of which was taken by Nuttall in "Missouri". Among these are series from Fredericton reared from *P. tremuloides;* from Laniel, Que., reared from "poplar"; and from Aweme, Man., reared from "cottonwood". On the elytra

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of all, the sutural spot at the apical fourth is well developed, but it is not prolonged along the suture. Two-thirds of the specimens have no other markings. In the other third, the posterior sublateral spot, the median subsutural spot, or both are evident, but they are always small and often obscure. When present, the median subsutural spot is subcircular and is well separated from the suture. None of the specimens have more than these three spots except one from Aweme, in which the subsutural at the basal fourth is also present.

In *annosus emotus* the pale vestiture of the elytra is somewhat condensed on the pale areas to render a distinct pattern. In *annosus annosus* the vestiture is condensed on the same areas, but the pattern is feebly defined because most of the areas are not pale.

Chlamisus Raf.

Gressitt (1946) had noted that *Chlamisus* Rafinesque, 1815, must be used for the genus that has been designated as *Chlamys* Knoch, 1801 (*not* Bolton, 1798), *Arthrochlamys* Ihering, 1904, and *Boloschesis* Jacobson, 1924.

The author (1943, 1946) has pointed out that a knowledge of food-plants is extremely useful in segregating species in *Chlamisus*. However, study of the beetles is complicated by their habit of feeding occasionally on unexpected plants and by the existence of siblings within the genus. It follows that very careful studies of both food relationships and of distributional patterns are essential to an understanding of the species.

Near Ottawa, the author found adults that he identifies as *C. eubati* (Brown) in significant numbers on the flowers of *Potentilla fruticosa* L. *C. eubati* breeds on species of the subgenus *Eubatus* Focke, genus *Rubus* L., and apparently on no other plants. The beetles on *P. fruticosa* were collected during very late August and September. This suggests that *eubati* may feed briefly on plants other than its normal host while moving to and from *Eubatus* and its winter quarters. Occuring on *P. fruticosa* with *eubati* were numerous adults, and several pupae from which adults were reared, identified as *C. chamaedaphnes* (Brown). *Chamaedaphne calyculata* L., which is the only known host of this species, was growing with the *P. fruticosa*, but it was free of beetles. Except for the flowers of *P. fruticosa*, neither plant showed evidence of feeding. *C. calyculata* blooms in the spring, and *P. fruticosa* flowers later. *C. chamaedaphnes* prefers the flowers to other parts of *C. calyculata*, and it is possible that breeding adults moved to the *Potentilla* from the *Chamaedaphne* after the latter had ceased to bloom. These are examples of the complications that require very careful study, for sibling species requiring different food-plants may be implicated. *C. bebbianae* (Brown) and *C. tectus* (Brown) are examples of sibling species. *C. bebbianae* occurs widely and commonly in the Ottawa district and in southernmost Quebec. It feeds normally on a single species of willow, *Salix bebbiana* Sarg. This willow usually grows with others, but, while collecting intensively from willows for a number of years, the author has found neither adults nor larvae on the others, except for two larvae on *Salix descolor* Muhl. *C. tectus* is known from Walsingham, in southernmost Ontario, and from Natick, Massaschusetts; it feeds on *Corylus americana* Walt. About Ottawa, no species of *Chlamisus* feeds on *Corylus cornuta* Marsh., which is the hazel of that district. Because the male copulatory organ is dimorphic in *bebbianae*, some males of the latter can be separated from males of *tectus*. Otherwise the two species appear inseparable, and they are considered different only because it is scarcely possible that a species utilizing a single willow at Ottawa would breed on *Corylus* in

another faunal region. At Newport and Mount Uniacke, Nova Scotia, the author has taken long series of adults from *Alnus rugosa* (Du Roi) Spreng. In these, most of the females and some of the males differ from those of *bebbianae* and *tectus* in having the pygidium slightly less coarsely punctate, but other separating characters are lacking. Females found feeding on *Quercus* L. at Natick, Massachusetts, and in Livington County, Michigan, are separable from the others only in series, as they differ only in slight, inconstant characters of size, colour, and sculpture, and probably in sex ratio. They seem to represent a fourth sibling.

In *Chlamisus*, as in many others genera of the Chrysomelidae, the specimen of value is not a single beetle but is, rather, a series of beetles associated with one species of food-plant and from one locality or, preferably, one colony. Testing the abilities of one population to utilize the different food-plants of other populations should aid in establishing the status of suspected siblings in *Chlamisus*, as it has in other genera of the family.

***Chlamisus fragariae* n. sp.**

Belonging to the *plicata* complex (Brown, 1943). Males numerous. Length of males 3.2 to 3.5 mm., of females 3.4 to 3.8 mm. Copper-coloured, the colour constant; antennae and a spot, usually obscure, within the emargination of each eye yellow; the apical halves of the antennae infuscate; labrum dark; body shining, the elytra shining almost as strongly as the pronotum.

Elytral tubercles slightly less strongly developed, the entire dorsum otherwise as in *eubati* (Brown). Pronotum impunctate or virtually so, a very few extremely fine punctures sometimes evident in certain lights; the gibbosity relatively wide and moderately deeply divided. Elytra with the juxta-scutellar tubercles feeble or obselete.

Prosternal plate goblet-shaped, not varying sexually. Metasternum with large, close, well-defined foveae; first abdominal segment with very feeble foveae; these parts sculptured as in allied species. Apical ventral segment lacking foveae or rounded punctures; the sculpture largely transverse, fine, close, including smooth intervals only in the male, subvermiculate in part; this vermiculate sculpture irregular, as in *coryli* (Brown, 1946, p. 48), finer than in *eubati*. Pygidium punctate, finely rugose, and alutaceous; finely subvermiculate. Each anterior and middle tibia of the male with a single, strongly developed, spur-like process on the inner side at apex; the tibiae of the female lacking processes.

Male copulatory organ as in *eubati* (Brown, 1943, Fig. 2); the apex feebly deflexed and usually more bluntly pointed than in *chamaedaphnes* (Brown); the flagellum about seven times as long as wide and with its orifice occupying about one-third of its length.

Food-plant.—The cultivated strawberry, *Fragaria ananassa* Duchesne, which may not be a normal food-plant for the species. The species of *Chlamisus* are rarely abundant, probably because their larvae are heavily parasitized. Because of its unusual adults and case-bearing larvae, the genus attracted the interest of field naturalists, who, before 1900, reported all food-plants presently known in eastern America except *Chamaedaphne calyculata* L. C. *fragariae* has been extremely abundant in a small area in southeastern New Brunswick, where, during 1951, its adults and larvae caused serious damage to the strawberry, an economic plant previously unreported as a host for the genus. This suggests the possibility

that another plant, one that is not abundant enough to support the present population of *fragariae*, is the normal or primary host.

Holotype.—♂, Hatfield Point, Kings County, New Brunswick, Sept. 17, 1951 (G. T. Morgan), on *Fragaria ananassa* Duchesne; No. 5984 in the Canadian National Collection, Ottawa.

Allotype.—♀, same data.

Paratypes.—13 ♂, 20 ♀, same data.

C. fragariae is a trifle smaller and has the elytral tubercles a little less strongly developed; otherwise it resembles *eubati* and *coryli* very closely. In *eubati* the apical ventral segment is more coarsely vermiculate, and in *coryli* the pronotum shows numerous moderately coarse punctures in certain lights. Males of *fragariae* differ from all others known to the author, except those of *chamaedaphnes*, in having each anterior tibia armed with one, rather than with two, spur-like processes. In *chamaedaphnes* moderately coarse pronotal punctures are evident, and the apical ventral segment bears punctures and foveae that, though confluent in part and transverse, do not produce a finely vermiculate sculpture. Study of new material has shown that the male copulatory organ of *eubati* does not always have the apex as bluntly pointed and the median orifice as acutely angulate anteriorly as the specimen figured by the author (1943, Fig. 2); some specimens of both *eubati* and *fragariae* approach *chamaedaphnes* and *bebbianae* (Brown, 1943, Fig. 4) in these respects.

Chlamisus platani n. sp.

Chlamys plicata Popenoe and Marlatt (*not* Fabricius), 1889: 40-41 (in part), Pl. 1, Figs. 1-8.

Belonging to the *plicata* complex (Brown, 1943). Males scarce. Length of males 3.6 to 3.7 mm., of females 4.0 to 4.4 mm. Coppery red, the red colouration strong in all specimens, the colour constant; antennae, labrum, and a spot within the emargination of each eye yellow; the antennae not or scarcely darkened apically; the spot sometimes obscure. Usually opaque above, sometimes feebly shining, this depending on the light.

Pronotum with the strigose sculpture finer than in any allied species and, because of this fineness, as dull as the elytra; punctate, the punctures extremely obscure but always evident in certain lights, moderately coarse, sparse but numerous; the gibbosity relatively narrow, moderately deeply divided. Elytra with the tubercles, including the juxta-scutellars, well developed; the strigulose sculpture as in *alni* (Brown) and *plicata* (Fab.), finer than in other allied species.

Prosternum goblet-shaped, not varying sexually. Metasternum with large foveae and the first abdominal segment with obsolete, larger foveae as in allied species. Apical ventral segment foveate; the foveae obsolete and completely confluent posteriorly, producing there a roughened, alutaceous sculpture; the median impression of the female simply alutaceous. Pygidium alutaceous, with a few obsolete or shallow foveae, usually with numerous fine punctures. Each anterior tibia of the male with two small, inwardly-projecting, spur-like processes on the inner side at apex; these separated by a U-shaped notch; each middle tibia of the male and each front and middle tibia of the female with a single similar process.

Male copulatory organ as in *chamaedaphnes* (Brown) and as in the holotype of *bebbianae* (Brown, 1943, Fig. 4; 1944, Fig. 1a); the apex feebly deflexed and acutely pointed; the flagellum about seven times as long as wide and with its orifice occupying about one-third of its length.

Distribution.—Known from Ohio, Kansas, and South Carolina.

Food-plant.—The sycamore, *Platanus occidentalis* L.

Holotype.—♂, Lorain County, Ohio, Sept. 7, 1947 (J. A. Wilcox), on *Platanus occidentalis* L.; in the collection of Dr. J. A. Wilcox, New York State Museum, Albany.

Allotype.—♀, same data.

Paratypes.—2 ♂, 5 ♀, same data; 2 ♀, same data, but collected Aug. 24, 1947; 7 ♀, same data, but reared from larvae during July and August, 1947; 5 ♀, Greene County, Ohio, reared from larvae on *Platanus occidentalis*, July and August, 1947 (J. W. Wilcox). Paratypes are deposited in the Canadian National Collection and in the collection of the Ohio State University.

C. platani is distinguished primarily by the exceedingly fine strigulose sculpture of the pronotum and by the colour, which is unlike that of any allied species. In other characters, *platani* is similar to *alni*, *bebbianae*, and *tectus* (Brown, 1946), but it averages slightly larger than any of these.

It is *platani* that Popenoe and Marlatt reared from sycamore in Kansas. The author has seen a specimen reared in Riley County, Kansas, by Marlatt and also specimens collected from sycamore in South Carolina.

***Phratora purpurea kenaiensis* n. subsp.**

Length 3.9 to 5.2 mm. Blackish, usually with feeble greenish reflections above. Other characters as in *purpurea purpurea* Brown, 1951, and *purpurea novae-terrae* Brown, 1951.

Holotype.—♂, Moose Pass (mile 37.5 on the road north from Seward), Kenai Peninsula, Alaska; June 30, 1951; 1,000 ft. (W. J. Brown); on *Populus tremuloides* Michx.; No. 5978 in the Canadian National Collection, Ottawa.

Allotype.—♀, same data but collected June. 21, 1951.

Paratypes.—53, same data but collected from June 20 to July 6, 1951.

P. purpurea kenaiensis differs strikingly in colour from *purpurea purpurea*, which is purple above and distributed from Massachusetts to Yukon Territory, and from *purpurea novae-terrae*, which is coppery red above and restricted to Newfoundland. *P. purpurea kenaiensis* is larger than those subspecies, averaging about 0.4 mm. greater in length; because it differs from them only in size and colour, it is presumed to be only subspecifically distinct.

***Gonioctena* Chev.**

Gonioctena Chevrolat, 1837: 403 or 427.
Phytodecta Kirby, 1837: 213.

Gonioctena has been attributed to Redtenbacher, because he was the first to publish the name with a description of generic characters, and has been dated 1844 or 1845. *Gonioctena* Redt., lacking priority, has been considered a synonym of *Phytodecta* Kirby, 1837. However, in 1837 Chevrolat validated *Gonioctena* by listing in it previously described species, and his usage, as shown by Barber and Bridwell (1940, p. 4), was published between March 1 and July 5, 1837. *Phytodecta* Kby. was described in October of that year and therefore lacks priority.

***Gonioctena americana* (Schaeff.)**

Phytodecta arcticus Bechyné (*not* Mannerheim), 1948: 118, 123; Pl. 4, Fig. 153.
Phytodecta arcticus, ab. *guttifer* Bechyné, 1948: 123; Pl. 4, Fig. 152.

The specimens from "America bor." that Bechyné referred to *arctica* and to his aberration *guttifer* must be referred to *americana* (Schaeff.). Bechyné described the specimens as having the antennae shorter than in the European *nivosa* (Suffr.), and as having the legs and the anterior part of the head pale.

None of these are characters of *arctica* Mann.; *americana* is the only American species that possesses them and the length, 5.5 to 6 mm., required by Bechyné's descriptions.

Gonioctena arctica Mann.

Phytodecta occidentalis Bechyné (*not* Brown), 1948: 118, 124; Pl. 4, Fig. 154.

The specimen from "America bor." that Bechyné identified as *occidentalis* (Brown) should be referred to *arctica* Mann. (1853, p. 257) or to the subspecies described below. Bechyné described the antennae as long, as in the European *nivosa* (Suffr.), and the tibiae as bicoloured; *arctica* is the only American species that possesses these characters.

The types of *arctica* were taken from willow on the "Tschunuktnu" River of the Kenai Peninsula, Alaska, which, according to Mannerheim's map (1853, Pl. 2), is either Resurrection Creek or Sixmile Creek. These flow into Turnagain Arm of Cook Inlet at Hope and Sunrise respectively. Of 98 specimens taken from *Salix* at Moose Pass, about 30 miles south of the type locality, 19 are entirely blackish above. The others have the elytra red and each maculate with two subsutural and two or, usually, three sublateral spots; rarely the spots are more or less confluent longitudinally. The specimens with maculate elytra have the pronotum entirely blackish or with its sides, and sometimes with its apex also, broadly pale. The underside is blackish with, usually, the sides of the prothorax and apical segment pale. The antennae, except at base, and the legs, except usually for parts of the tibiae, are blackish. Of eight specimens reared from *Salix* sp. at Lawing, Kenai Peninsula, five have the elytra entirely red, and four of these have the pronotum entirely blackish. Series from northern Canada are typical enough except for 73 specimens from Churchill, Man., which average a trifle small and usually lack the posterior sublateral spots. The Churchill specimens are from a single colony, which occured about four miles beyond the trees; a specimen from Padlei, N.W.T., was taken three or four miles from the nearest trees; and the Lawing larvae were taken at 2300 feet, about 1000 feet above the trees. The other series were taken within, but near, the limit of trees. The localities represented in the Canadian National Collection are: Moose Pass and Lawing, Alaska; Kluane, Dezadeash Lake, and Haines Junction in southwestern, and Selkirk in central, Yukon Territory; Reindeer Depot (Mackenzie Delta), Sawmill Bay (Great Bear Lake), Norman Wells, and Padlei (lat. 61° 55′, long. 97° 15′), Northwest Territories; Churchill, Manitoba. Thus typical *arctica* occurs near the limit of trees from the Kenai Peninsula to Hudson Bay.

Gonioctena arctica alberta n. subsp.

Phytodecta arctica Mann., Brown, 1942: 100 (in part).

Punctures of the abdomen beneath constantly much sparser and finer than in typical *arctica;* most of them, even on the sides, separated by distances equal to or greater than their diameters; those at middle about one-fourth as large as the punctures of the sides of the metasternum in *alberta*, about one-half as large as those metasternal punctures in typical *arctica*. Pronotum, except in one paratype from Banff, less strongly alutaceous and therefore more strongly shining than in typical *arctica*. Colour evidently varying as in typical *arctica;* the paratype from Glacier Park with the pronotal sides narrowly pale and the sublateral spots of the elytra longitudinally confluent; the other specimens as described previously by the author (1942, p. 100).

Holotype.— ♂, Nordegg, Alberta, June 10, 1921 (J. McDunnough); No. 6006 in the Canadian National Collection, Ottawa.

Allotype.— ♀, same data.

Paratypes.—1 ♀, same data as holotype; 1 ♂, 2 ♀, Banff, Alberta, July 13 and 18, 1922 (C. B. D. Garrett); 1 ♂, Glacier Park, Montana, July 23, 1924.

In the holotype, the pronotal sides are much more strongly arcuate than in the other specimens of *alberta* and the specimens of typical *arctica*, in which the pronotal sides are moderately variable.

Galerucella stefanssoni Brown

Galerucella stefanssoni Brown, 1938: 36.

This species has been known only from two females taken at Langton Bay (lat. 69° 22′, long. 125° 11′), N.W.T. The author found a prepupa, from which an adult was reared, beside an imbedded stone at Kidluit Bay (lat. 69° 44′, long. 134° 30′), N.W.T., on July 30, 1948, and took 24 adults from the food-plant, *Rubus chamaemorus* L., at Reindeer Depot (lat. 68° 42′, long 134° 03′), N.W.T., between August 13 and 17, 1948. At Reindeer Depot the species occurred on the treeless tundra of the Caribou Hills; the food-plant grew on sphagnum, which thawed during the summer to a depth of 11 to 13 inches. The species is the only galerucid that is truly Arctic. Few American galerucids extend into the boreal forest, and the northermost of these, *Galerucella nymphaeae* (L.) and *G. decora* (Say), find their northern limits far from the limit of trees.

G. stefanssoni is from 3.0 to 3.8 mm. in length. It varies from dull brownish-yellow to pale red above; the antennae are usually infuscate or dark except at the base. The tibiae are mutic except for the middle pair of the male; each of these bears a small mucro on the inner side of the apex. In the male, the apical ventral segment is broadly emarginate and triangularly impressed; the impression attains the middle or the basal third of the segment and is as wide, or almost as wide, as long. The male copulatory organ is symmetrical, evenly curved, and rather bluntly pointed. In the female, the apical ventral segment is truncate or very feebly emarginate and its median line is sometimes briefly and indistinctly impressed at the apex.

G. stefanssoni resembles no other American species, but it does resemble and is closely allied to the European *G. tenella* (L.) and *G. pusilla* (Duft.). In all of these, the inner margin of the elytral epipleura remains distant from the outer margin and ends shortly before the elytral apex, the middle tibiae are mucronate in the male, the anterior coxal cavities are narrowly closed behind and are separated by a cariniform prosternal process, and the middle coxae are narrowly separated. In *stefanssoni* the body is more broadly oval, and the antennae are less elongate than in the European species; the male copulatory organ is more bluntly pointed than in *pusilla* and a trifle less bluntly than in most specimens of *tenella*.

Galerucella quebecensis Brown

Galerucella quebecensis Brown, 1938: 36.

This unusual species, described originally from specimens taken at Knowlton and Duparquet, Que., occurs also at Cacouna, Que., and Ingramport, N.S. Thus it occurs from southwestern and southernmost Quebec to Gaspé and southern Nova Scotia. At Ingramport it was found abundantly on *Potentilla palustris* (L.) Scop., which is its food-plant. Most specimens are pale, dull, yellow above, instead of pale brown like the types, and all have the scutellum largely blackish. The obscure, posthumeral vittae, which are evident in the types, are lacking in most of the other specimens, which simply have the humeral umbones

infuscate. The species has the characters decribed above for *stefanssoni*, *tenella*, and *pusilla* but has on each of the anterior tibiae, as well as on each of the middle tibiae, a small mucro at the apex in the male. This character is not known to the author in any other species of the heterogeneous assemblage now referred to *Galerucella* Crotch.

Kytorhinus prolixus (Fall)

Mylabris prolixus Fall, 1926: 204.
Kytorhinus prolixus (Fall), Bridwell, 1946: 53.

This remarkable bruchid, which was described from specimens taken at McKinley Park Station, Alaska, occurs on the Mackenzie River at Reindeer Depot and Norman Wells, N.W.T., and at Edmonton and Calgary, Alta. At Rendeer Depot, it was abundant on *Hedysarum alpinum* L. var. *americanum* Michx. (det. A. E. Porsild), which was evidently its food-plant.

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Notes on the Parasitism and Food Habits of the European Earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae)[1]

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Introduction

In 1936, 1937, and 1938 several colonies of *Bigonicheta setipennis* (Fall.), a dipterous parasite, were liberated in Vancouver, British Columbia, to aid in the control of the European earwig, *Forficula auricularia* L. During September and October, 1950, an investigation was initiated to determine the abundance and distribution of this parasite and, if possible, to obtain colonies for release in Newfoundland. Approximately 6,000 of *B. setipennis* were reared from 50,000 trapped earwigs.

During this investigation a significant fluctuation in the daily catch of earwigs was observed. This was found to have been caused by fluctuations in temperature, temperature range, and wind velocity (Chant and McLeod, 1952). It was also observed that more earwigs were caught in traps placed in trees than in traps placed on the ground.

In September, 1951, the investigation was continued to determine the relative abundance and degree of parasitism of earwigs in trees and on the ground, and, later, also the amount and type of food that they consumed.

Methods

The mass collection of earwigs was accomplished by the use of traps already described (Chant and McLeod, loc. cit.). On September 27, 1951, aproximately 40 traps were placed in laburnum, maple, beech, willow, and hawthorn trees and 160 on the ground. The earwigs were collected from the traps each day and were transferred to a collecting tin 9 inches square and 10 inches deep. This container had a circular hole in the top through which the earwigs dropped when the traps were opened. A band of grease was placed on the under surface of the top to prevent their escaping through the open hole.

At the laboratory the earwigs were anaesthetized with carbon dioxide gas. The gas was released into the collection container through a rubber hose connected to a low pressure gauge attached to a metal cylinder, in which the gas was held under pressure. An exposure of 1 minute at 1-pound pressure was sufficient to immobilize the earwigs until they were counted, sorted according to sex, and placed in rearing cages.

The rearing cages were 2 feet by 2 feet by 2 feet. The tops were open except for a 4-inch cap with a 2-inch face projecting below the inner edge of the cap. A layer of grease was applied to the under surface of the cap; this prevented the earwigs from escaping. The 2-inch face prevented the clothing of the operators from coming in contact with the grease. Traps were placed on the bottoms of the cages to provide a place for the earwigs to hide during daylight.

The earwigs collected in the trees were reared separately from those collected on the ground; also, the males and females of each group were placed in separate rearing cages. Dipterous parasite puparia were collected and recorded daily to determine the number of parasites in each group. These caged earwigs were fed on lettuce, sliced carrot, and meat meal. Other groups of earwigs were supplied with these foods and dahlia blooms, and colonies of the cabbage aphid,

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Brevicoryne brassicae (L.); the woolly apple aphid, *Eriosoma lanigerum* (Hausm.); a willow aphid, *Clavigerus smithiae* Monell; and 3 species of scale insects, the European fruit lecanium, *Lecanium corni* Bouché, the oystershell scale, *Lepidosaphes ulmi* (L.), and *Aspidiotus* sp.

A red lamp with a wave length of 650 angstrom units at 50 per cent transmittance was used when observing the earwigs after it was found that incandescent and fluorescent lights disturbed their normal nocturnal activity.

Results

In 12 days, 2,662 earwigs were obtained from 40 traps placed in trees and 2,741 from approximately 160 traps on the ground. On the basis of 1 trap-day for each 24-hour period that each trap was in position, the traps placed in trees had been in position for 467 trap-days, and those placed on the ground for 1,612. Thus, 5.7 earwigs were obtained per trap-day from the traps placed in trees, and 1.7 from those placed on the ground, i.e., there were 3.3 times as many earwigs caught in trees as on the ground.

When emergence was complete, 128 parasites had emerged from the 2,662 tree-caught earwgs, and 55 from the 2,741 ground-caught ones. This difference is highly significant. There was no significant difference, however, between the numbers of parasitized males and females in either group.

A group of 160 caged earwigs was given the normal laboratory food, lettuce, carrot, and meat meal, and also dahlia blooms and several large colonies of the cabbage aphid, *B. brassicae*. During a 5-day period these earwigs consumed 2,735 mg. of dahlia stamens and pollen and 6,590 individuals of *B. brassicae* weighing 2,745 mg. Hence, each earwig fed on 8 or 9 aphids each night throughout the period. They did not consume any lettuce, carrot, or meat meal. When the aphid colonies were disturbed by the earwigs many of the aphids wandered over the sides of the cage, but were eventually found and consumed. Neither syrphid larvae present in these colonies nor parasitized *B. brassicae* in the mummified stage were consumed.

Two other species of aphids, the woolly apple aphid, *E. lanigerum*, and a willow aphid, *C. smithiae*, and 3 species of scale insects, the European fruit lecanium, *L. corni*, the oystershell scale, *L. ulmi*, and *Aspidiotus* sp., were supplied to other groups of earwigs in the absence of any plant food. In one night a group of 200 caged earwigs, feeding only on the more mature individuals, consumed more than 2,000 scales of the genus *Aspidiotus*. Another group of approximately 125 earwigs consumed 580 individuals of *E. lanigerum* in the same length of time, feeding on those parasitized by *Aphelinus mali* (Hald.) as well as on unparasitized ones. The following night the same group consumed 900 individuals of *C. smithiae*. A third group of 293 earwigs consumed 537 overwintering individuals of *L. corni* in one night, and a final group fed upon the overwintering eggs of *L. ulmi*.

Discussion

Many more earwigs were obtained from traps placed in trees than from traps on the ground at the bases of the trees. In determining the reason for this greater abundance in trees it was assumed that the earwigs frequented the trees in search of food. There was no evidence of foliage injury and it was assumed that they were in search of animal food in the form of small insects.

Investigators, including Glendenning (1947) and Crumb, Eide, and Bonn (1941), have reported that the later stages of the earwig are omnivorous: they feed on many species of insects and on a wide range of plant species including

grass, dahlia, carnation, chrysanthemum, celery, potato, seedling plants of various species, and lower forms of plant life such as mosses, lichens, and algae.

In the laboratory, when given a choice of plant and animal food the earwigs consumed approximately equal amounts by weight of each. When they were given a choice of plant food, they consumed dahlia stamens and pollen, the plant food with the highest protein content, in preference to other parts of dahlia blooms, lettuce, or sliced carrots. When given a choice of animal food, they chose aphids or scale insects in preference to meat meal.

More than twice as many parasites were obtained from earwigs caught in trees as from approximately the same number caught on the ground. The greater number of parasites found in the earwigs caught in trees may be explained by the presence of a limited number of suitable hiding places available to the earwigs in the trees, resulting in most of the available places being occupied by a number of these insects during daylight. On the other hand, because there are innumerable hiding places available to the ground-frequenting earwigs, no one place is particularly crowded. It has been observed during the laboratory propagation of *B. setipennis* that they are attracted to the earwigs by their odour. It is therefore reasonable to assume that the majority of these parasites are attracted to the crowded hiding places in the trees and larviposit there.

Summary

In Vancouver, B.C., during late September and early October, 1951, 3 times as many individuals of the European earwig were obtained from traps placed in trees as from traps placed on the ground. In the laboratory, the earwigs consumed approximately equal amounts by weight of plant and animal food. No evidence of their eating plant food was observed on the trap trees. The greater abundance of the earwig in trees must therefore have resulted from the presence of animal food in the form of various species of small insects such as aphids and scales.

Approximately twice as many parasites were obtained from the tree-caught earwigs as from the same number of ground-caught earwigs. It is suggested that the concentrated earwig population in the trees was more attractive to the parasites than the diffuse, ground-frequenting population.

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Timing of DDT Applications for Control of Caterpillars on Cabbage[1]

By W. G. MATTHEWMAN[2], D. G. HARCOURT[2], AND J. P. PERRON[3]

Introduction

Three species of caterpillars commonly attack cabbage at Ottawa, namely, the imported cabbageworm, *Pieris rapae* (L.), the larva of the diamondback moth, *Plutella maculipennis* (Curt.) and the cabbage looper, *Trichoplusia ni* (Hbn.). All three species are readily controlled with DDT sprays or dusts but the timing of the applications is important. Growers sometimes begin dusting or spraying too early, wasting one or more applications, or they delay the first application until mid-August, when severe damage has already occurred. This paper is a report on four seasons' experiments at Ottawa, 1947 to 1950, to determine the number and timing of applications of DDT required for control of caterpillars on late cabbage.

Species, and Problem of Control on Early Cabbage

Cabbage at Ottawa is usually transplanted from the seedbed to the field in two periods, the early crop, for summer use, in late May; the late crop, for fall and winter use, in late June. The early crop, maturing in July, frequently escapes severe attack by caterpillars. When it is severely attacked the heads have usually formed; hence the insecticide recommended is a rotenone spray or dust. Only one or two applications are required, in late June and/or early July, and timing is not an important factor. The imported cabbageworm is the predominant species attacking early cabbage, the diamondback moth forming a smaller but significant part of the total population. Numbers of the cabbage looper are usually negligible.

Species, and Problem of Control on Late Cabbage

The late crop is attacked from July to October, but the population of the species complex usually reaches its peak in August. The imported cabbageworm predominates in July and usually in the first half of August; the diamondback moth, in September and October and sometimes in August. The cabbage looper population, probably rarely more than five per cent of the total, usually reaches its peak in late August or early September; it is relatively of most importance in September, when the maturing larvae sometimes bore into the cabbage heads.

The imported cabbageworm is the species largely responsible for the damage to late cabbage, and insecticide applications are primarily directed against it. Records and observations for the past 12 years at Ottawa show that the infestations vary greatly from year to year in both intensity and peak. The peaks of egg-laying, followed shortly after by the peaks of larval hatching, may be at mid-July as in 1946, 1948, and 1950; late July or early August as in 1941, 1944, 1949, and 1951; mid August as in 1942, 1943, and 1947; or late August as in 1940 and 1945. Two strategically timed applications of DDT before and about the time of the population peaks should give satisfactory control on late cabbage; because it is difficult or impossible to forecast the time of occurrence of the peaks, it is desirable to be able to recommend to growers a schedule of application that will compensate for average yearly population variations.

Material and Methods

Material and Application

The insecticide used in all four years' experiments was a three per cent DDT dust (a commercial product from technical DDT of 88° C. setting point; diluent,

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TABLE I
Schedules of DDT Application on Late Cabbage Against Caterpillars, Ottawa, 1947 to 1950

	Dates of application			
	July	August		
Schedule	20	2	15	30
1	X*	—	—	—
2	X	X	—	—
3	X	X	X	—
4	X	X	X	X
5	—	X	—	—
6	—	X	X	—
7	—	X	X	X
8	—	—	X	—
9	—	—	X	X
10	—	—	—	X
11	—	—	—	—

*Application of three per cent DDT dust.

principally talc); it was applied with rotary hand dusters at average rates of 35 to 40 pounds per acre. Each year there were 11 schedules, including the check, of from zero to four applications. The dates of application were approximately July 20, and August 2, 15, and 30, with slight variations due to weather from year to year.

The experimental method was based on Glasgow's (1940) plot arrangement for timing the applications in a control program; the principle of this is illustrated in Table I, in which each X represents an application of DDT. The plots of schedule 1 received only the one application, on July 20; those of schedule 2, two, on July 20 and August 2; those of schedule 3, three, on July 20, and August 2 and 15, and so on.

Location, Arrangement, and Size of Plots

The experimental plots were in growers' fields, at Aylmer, Que., in 1949, and at City View, Ont., in the other three years. The individual plots, which averaged one-fiftieth of an acre in size, were in randomized blocks; they were replicated four times in 1947 and six times in 1948, 1949, and 1950. The experimental areas were as follows: 1947, four-fifths of an acre; 1948, 1⅓ acres; 1949, 1¼ acres; 1950, nine-tenths of an acre. The variety of cabbage in all four experiments was Penn State Ballhead.

Records on Populations

To indicate the population fluctuations of the imported cabbageworm in July and August, records were taken at fortnightly intervals on the number of eggs of *Pieris rapae* laid on 100 cabbage plants near the experimental plots or, sometimes, in the check plots of the experiments. The populations of the species

complex were high in 1947 and 1948, moderate in 1949, and low in 1950. In 1950 an analysis of the species percentages for each of the stages was made in replicated plots of cabbage adjacent to those of the timing experiment. Those for the larvae (Table II) show that the larval population of the diamondback moth from mid-July through October was almost as high as that of the imported cabbageworm; it was actually higher in 1951, when the species percentages of 15,000 larvae from July 3 to October 31 in a similar study were as follows: imported

TABLE II

Species Percentages of Caterpillars Attacking Late Cabbage
Ottawa, July 14 to October 26, 1950

Date	Total per 100 plants	Percentage of total		
		Pieris rapae	*Plutella maculipennis*	*Trichoplusia ni*
July 14	481	98.8	1.0	.2
July 20	451	96.9	2.9	.2
July 27	465	93.8	6.0	.2
August 4	337	84.6	15.1	.3
August 11	162	28.4	63.0	8.6
August 17	287	30.7	68.3	1.0
August 25	723	23.2	74.3	2.5
August 31	267	40.1	52.8	7.1
September 7	553	35.1	60.0	4.9
September 16	183	42.1	51.9	6.0
September 21	223	34.1	58.7	7.2
September 28	327	28.4	66.1	5.5
October 5	198	26.8	70.7	2.5
October 13	127	14.2	84.3	1.5
October 19	293	3.8	93.2	3.0
October 26	79	15.2	82.3	2.5
Total	5,156			
Means		50.0	47.2	2.8

cabbageworm, 41.2; diamondback moth, 58.6; cabbage looper, 0.2. Observations in previous years suggested that although the larval populations of the diamondback moth were not so high as in 1950 and 1951, they were higher than the literature suggests, forming a significant percentage of the total. Nevertheless, because the larvae of the imported cabbageworm consume much more foliage per individual than do those of the diamondback moth, the former is the more important species.

Criterion of Effectiveness

The criterion of effectiveness was foliage injury two to five weeks before harvest, on September 30 in 1947, September 8 in 1948, September 6 in 1949, and September 26 in 1950. Foliage injury records were taken at harvest as well, but they proved less reliable. Yield records were not obtained because the growers harvested the heads at intervals in September or sold the cabbage as a whole in the field. The foliage injury records were taken independently by two observers and the results averaged. All the plants in the experimental plots were graded for injury to the heads and leaves; there was no attempt to differentiate between the feeding injury of the three species of caterpillars because experience had shown that this was impractical, and in fact, almost impossible. The grades of injury in the four years' experiments were as follows:—

Grade 1: None; very slight—from one to 10 holes; slight—11 or more holes, up to four leaves skeletonized.

Grade 2: Moderate—five to 10 leaves skeletonized; severe—11 to 14 leaves skeletonized; very severe—15 or more leaves skeletonized.

Results

Table III shows that almost complete control of caterpillars attacking late cabbage was obtained in each of the four years with four applications of three

TABLE III

Control of Caterpillars on Late Cabbage at Ottawa with 1 to 4 Applications of 3 Per Cent DDT Dust, on the Basis of Foliage Injury on September 30, 1947; September 8, 1948; September 6, 1949; and September 26, 1950

Schedule of application				Late cabbage plants								Percentage control***				
				Number examined				Per cent grade 2**								
July 20	August 2	August 15	August 30	1947	1948	1949	1950	1947	1948	1949	1950	1947	1948	1949	1950	Mean
X*	X	X	X	520	932	992	513	0	3.1	3.5	0	100	97	96	100	98
X	X	X	—	537	946	999	523	5.0	5.1	4.0	0	95	95	95	100	96
X	X	—	—	508	954	997	523	66.5	8.9	11.7	7.1	32	91	87	84	73
—	X	X	X	522	957	961	533	0.6	83.4	36.4	.6	99	14	58	99	67
—	X	X	—	535	972	1,015	524	15.5	80.9	43.1	.6	84	17	51	99	63
—	X	—	—	520	995	994	510	49.6	88.3	44.1	8.0	49	9	50	82	47
—	—	X	X	531	933	1,013	511	67.4	93.7	63.6	6.5	30	4	27	86	37
X	—	—	—	526	933	1,034	517	96.8	32.0	61.5	29.2	1	67	30	36	34
—	—	X	—	519	943	972	524	81.5	93.4	77.1	13.7	17	4	12	70	26
—	—	—	X	530	977	966	512	94.7	94.1	73.4	18.0	3	3	16	60	21
—	—	—	—	536	938	1,016	521	97.9	97.4	87.5	45.5	—	—	—	—	—
				Difference required (P = .05)				11.8	8.1	3.0	6.9					
				for significance (P = .01)				20.9	10.8	5.4	12.0					

*Application of 3% DDT dust.
**Plants with moderate, severe, or very severe foliage injury.
***Calculated by Abbott's formula.

per cent DDT dust on July 20 and August 2, 15, and 30. Three applications beginning on July 20 gave almost as good control. Three applications beginning on August 2 gave variable protection: excellent in 1947 and 1950, unsatisfactory in 1948 and 1949. Two applications gave highly variable results: on July 20 and August 2, unsatisfactory protection in 1947 and good protection in the other three seasons; on August 2 and 15, good protection in 1947, unsatisfactory in 1948 and 1949, and excellent in 1950; on August 15 and 30, satisfactory protection only in 1950.

Single applications generally gave unsatisfactory results, occasionally good. The most frequently effective single applications were those of August 2.

Observations showed that schedules of application starting before the population peaks of the imported cabbageworm usually gave the best protection against injury by the species complex.

Discussion of Results

Four years' results show that almost complete control of caterpillars attacking late cabbage at Ottawa can be obtained in average years with four applications of three per cent DDT dust about July 20 and August 2, 15, and 30. Occasionally, when the peak of infestation occurs at the end of August as in the outbreak year of 1940, or in 1945, there may be severe injury to the heads in September, but such late injury is rare; usually, the September injury is but moderate and readily preventable by the August 30 application.

In years when the infestation of the imported cabbageworm lessens rapidly in August, as it frequently does because of natural control, and the populations of the other two species are not particularly high, the August 30 application may be eliminated. Under these conditions, three applications will probably give as satisfactory control as four provided they are begun about July 20, but three is the minimum number of applications that will give consistently good control.

In 1950, a preliminary test suggested that three applications on July 20 and August 10, and 30 may suffice; however, this schedule is not yet recommended.

Although in most years the plants outgrow the injury of mid- and late-July by the time of harvest, and the July 20 application is thus apparently unnecessary, the 1948 results (Table III) show that it is unwise to omit the July 20 application. Observations in these experiments and in previous years suggested that about one year in four the July 20 application is likely to be more important than any of the others. Without it the plants may be considerably damaged regardless of the number of subsequent applications. Further, Ullyett (1947) has shown that in South Africa if insecticides are to be applied against the diamondback moth they should be applied at an early stage in the infestation to minimize damage to the parasites and predators of the insect. For the same reason it probably would be undesirable for growers at Ottawa to delay the applications until early- or mid-August, irrespective of the immediately apparent degree of protection obtained.

Single applications at Ottawa are frequently a waste of time and materials and are not recommended.

Although there were no yield data in the experiments to prove that prevention of caterpillar injury will give increased yields, Hervey (1941), among others, has shown that caterpillar injury does cause stunting of the plants. Whether or not caterpillar control is worth while from the standpoint of in-

creased yields, more and more growers of late cabbage at Ottawa consider it a paying proposition to dust or spray their plants to obtain a product of better quality. This has largely occurred since the introduction of DDT, which is spectacularly more effective than the proprietary calcium arsenate dusts, or even the lead arsenate dusts, formerly in use. DDT also gives good control of the zebra caterpillar, *Ceramica picta* (Harr.), which accasionally attacks cabbage in significant numbers, whereas the arsenicals do not.

In the past 12 years at Ottawa there have been four years, 1942, 1943, 1946, and 1950, when the infestations of caterpillars were so light that insecticide applications on late cabbage might have been a waste of money; four years, 1941, 1945, 1949, and 1951, when they probably would have been profitable; four years, 1940, 1944, 1947, and 1948, when they should have been highly profitable. Apparently control treatments are desirable about two years in every three at Ottawa, particularly in plantings of two acres or less in size, which are the usual rule in this area.

The writers believe that for the Ottawa district DDT applications on or about July 20 and August 2, 15, and 30 will give better results on late cabbage than leaving the dates to the judgment of the grower. This recommendation is probably applicable to eastern Ontario and western Quebec as well. With modifications, it should be applicable to southwestern Ontario; there, where there may be an overlapping of early and late plantings, DDT should not be applied to mid-season cabbage, of course, within 21 days of harvest. Because of the longer growing season and the greater prevalence of the cabbage looper in that area, an application of DDT in September is probably desirable.

Discussion of Methods

Glasgow's (1940) plot arrangement for timing the applications in a control program was effectively used in these experiments, and in previous experiments at Ottawa on the control of the caterpillars with lead arsenate. The same method, or a modification of it, was used in Canada in experiments on the control of the onion maggot by Matthewman, Dustan, and Davis (1942) and of aphids attacking potatoes by Adams and Kelly (1950) (in litt.). Recently, it has been used in experiments by officers of the Division of Entomology on the control of the onion maggot in Quebec, the carrot rust fly in Ontario, and root maggots attacking turnips in Prince Edward Island and Manitoba. It is obviously of most value when the experiments are repeated for several years. For this purpose it is highly desirable first to select the most satisfactory insecticide, concentration, and rate of application, and the most probably effective intervals and dates of application. In repeating the experiments it is, of course, essential to keep the dates constant.

Summary

Early and late cabbage, which are usually transplanted from seedbed to field in late May and late June, respectively, at Ottawa, are attacked by three species of caterpillars, namely, the imported cabbageworm, the larva of the diamondback moth, and the cabbage looper.

On early cabbage, the three species are controlled by one or two applications of rotenone in late June or July.

On late cabbage, all three species are readily controlled by applications of DDT, but the timing of the applications is important.

Observations at Ottawa have shown that applications of DDT directed primarily against the imported cabbageworm will control the species complex

and that best results are secured when the first application is made before the population peak of the imported cabbageworm.

Four years' experiments, 1947 to 1950, on the timing of applications of three per cent DDT dust on late cabbage show that four applications about July 20 and August 2, 15, and 30 will give excellent control of caterpillars at Ottawa in an average year. Three applications beginning on July 20 may suffice in years when the population of the imported cabbageworm falls off rapidly in late August, but three is the minimum number of applications that will give consistently good control.

Insecticide applications on late cabbage are apparently desirable about two years in three at Ottawa.

Acknowledgments

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Canadian Species of *Orocastus* and *Auridius* (Homoptera: Cicadellidae)[1]

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Leafhoppers of the genera *Orocastus* and *Auridius* are locally abundant in grassland regions in Western Canada. They are small insects, the males golden yellow and the females stramineous in colour. The two genera are distinguished from each other by characters of the internal male genitalia. The species are distinguished primarily by these characters and by the form of the seventh sternite of the female. There has been some confusion between the species, partly because the sexes were wrongly associated by some authors and partly because the extent of the individual variation was not appreciated fully. The following are descriptions and illustrations of the distinctive characters of the four species found in Canada, with notes on the distributions and variation. One species new to science is described and one species is reduced to synonymy.

Orocastus perpusillus (Ball & DeL.)

Figs. 1, 5, 14

Deltocephalus perpusillus Ball and DeLong, 1926: 241.

Length 2.6-3.3 mm. Male bright orange-yellow, female yellowish stramineous, without darker markings. Sub-brachypterous, or macropterous. The aedoeagus and the female seventh sternite are distinctive.

This species resembles superficially a species of *Auridius* but it is a smaller insect and the males are usually sub-brachyterous. It is easily recognized by the

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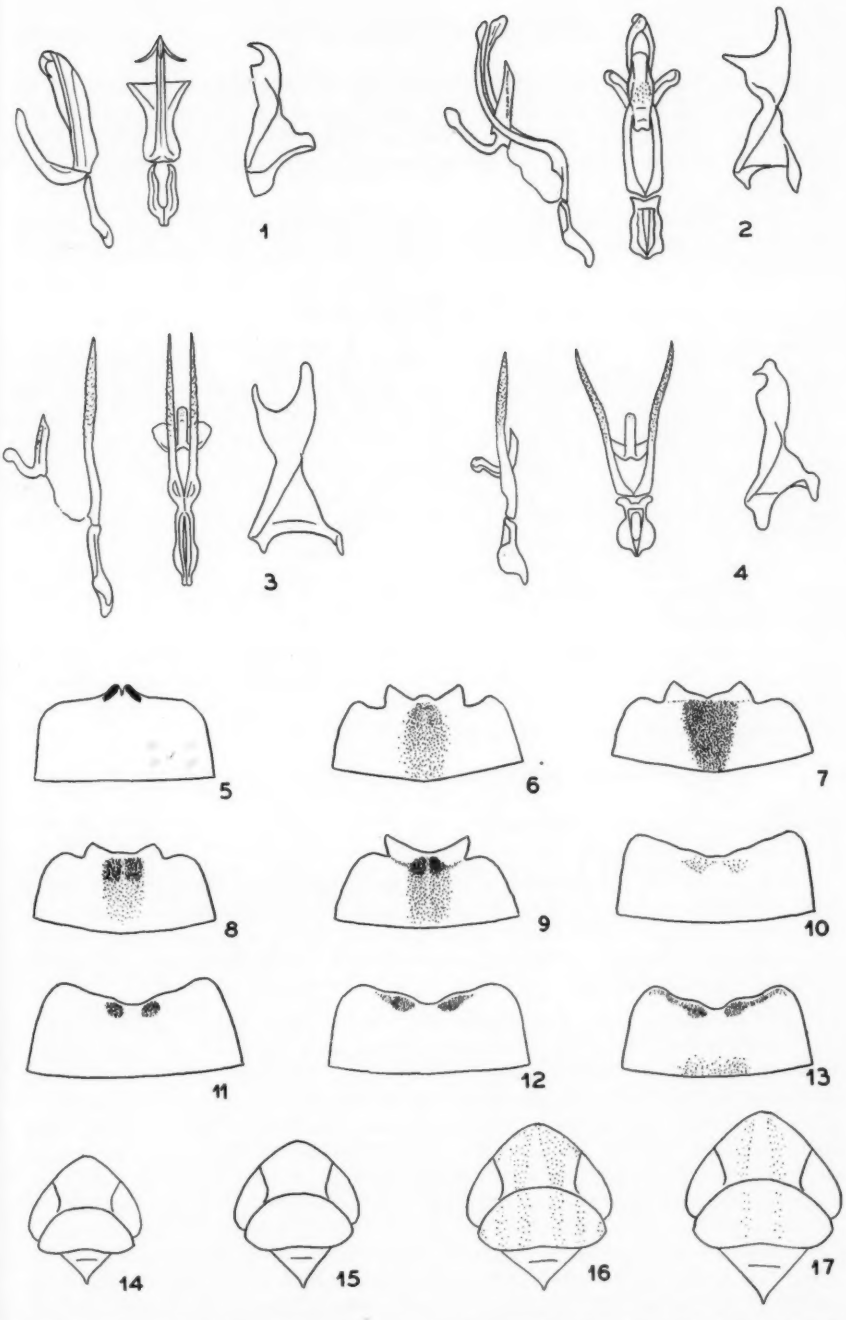

Figs. 1-17. 1-4, aedoeagus, connective, and paraphyses, lateral and ventral views, and style of: 1, *Orocastus perpusillus* (Ball & DeL.); 2, *Auridius flavidus* n. sp.; 3, *A. ordinatus* (Ball); 4, *A. auratus* (G. & B.). 5-13, seventh sternite of female of: 5, *O. perpusillus*; 6-9, *A. ordinatus*; 10-13, *A. auratus*. 14-17, head, pronotum, and scutellum of: 14, *O. perpusillus* (male); 15, *A. flavidus* (male); 16, *A. ordinatus* (female); 17, *A. auratus* (female).

genitalic characters. The female seventh sternite was figured by Sanders and DeLong (1920) and by DeLong (1926) as of *auratus* and the male genitalia were figured by DeLong and Sleesman (1929) as of *subrutilus*. According to Oman (1947), all specimens except the holotype in the type series of *subrutilus* are of *perpusillus*.

Specimens examined from: Saskatoon, Saskatchewan; Experimental Range Station, Manyberries, Alberta; and Soda Creek and Chimney Creek, British Columbia.

Auridius flavidus n. sp.

Figs. 2, 15

Length 2.8 mm. Macropterous. Pale golden-yellow. Vertex rounded and bluntly pointed, slightly shorter than in *auratus*. Male genitalia in lateral view with paraphyses bent upward near base and then evenly curved; in dorsal view crossing each other beyond middle and overlapping or crossing at apices; each paraphysis with a flattened expansion at apex. Shaft of aedoeagus stout, tapering in lateral view, ornamented with small spines at sides and beneath. Style with apical region broad and flattened, with a tapering, bluntly pointed process at apex and a shorter, tapering, lateral process.

This species can be distinguished readily from *auratus* and *ordinatus* by the sinuate paraphyses with their expanded apices, and by the form of the style. The female is unknown.

Holotype, ♂.—Experimental Range Station, Manyberries, Alberta, July 14, 1929 (Range Insect Survey). No. 6010 in the Canadian National Collection, Ottawa.

Paratypes.—2 ♂, same data as holotype.

Auridius ordinatus (Ball)

Figs. 3, 6-9, 16

Deltocephalus ordinatus Ball, 1899: 307.
Deltocephalus helvus DeLong, 1926: 78. New synonymy.

Length 2.7-2.6. Macropterous or sub-brachypterous. Male golden yellow without darker markings. Female stramineous, often without darker markings but often with two broad, longitudinal bands on vertex and four bands or pronotum faintly brownish. There is some variation in the form and markings of the female seventh sternite.

The seventh sternite distinguishes the female from that of *auratus*. The paraphyses, aedoeagus, and style distinguish the male from that of *flavidus*, and the style and the connective distinguish it from *auratus*. Individual variation in the form and markings of the female seventh sternite covers the differences between *ordinatus* and *helvus*. The former, as described by Ball, is a form that has the darkened bands on the vertex and pronotum, and the posterior margin of the female seventh sternite with a short, rounded, median projection (Fig. 6), whereas *helvus*, as described and figured by DeLong, is a form without the darkened bands on the vertex and pronotum and with the posterior margin of the female seventh sternite concave medially and with a small median notch (Fig. 7). As mentioned above, the bands on the vertex and pronotum may be present or absent and the form of the female seventh sternite varies considerably. The extent of the latter variation is indicated in Figs. 6-9, which are of specimens collected in the one locality at the one time.

Specimens examined from: Saskatoon, Saskatchewan; Glenwood, Alberta; and Quesnel and Soda Creek, British Columbia.

***Auridius auratus* (G. & B.)**

Figs. 4, 10-13, 17

Deltocephalus auratus Gillette and Baker, 1895: 85.
Deltocephalus exectus DeLong, 1926: 78.
Deltocephalus subrutilus DeLong & Sleesman, 1929: 103.

Length 3.2-3.8 mm. Macropterous or sub-brachyterous. Male golden yellow without darker markings. Female stramineous, usually without darker markings but sometimes with indications of two brownish, longitudinal bands on the vertex and four on the pronotum.

This species is, on the average, slightly larger than *ordinatus* and less brightly coloured. It can be distinguished readily from that species by the female seventh sternite, which varies somewhat in form and markings (Figs. 10-13), and by the style and the connective. It can be distinguished from *flavidus* by the paraphyses and the style. The holotype female of *exectus* is a typical specimen of *auratus*, according to Oman (1947) and confirmed by DeLong's (1926) figure. Oman (1947) states that the holotype of *subrutilus* is of *auratus*, though the remaining specimens in the type series of *subrutilus* are of *perpusillus*. The female figured by Sanders and DeLong (1920) and by DeLong (1926) as *auratus* is of *perpusillus* and the male figured by DeLong and Sleesman (1929) as *auratus* is of *ordinatus*.

Specimens examined from: Saskatoon, Saskatchewan; and Soda Creek, Chimney Creek, Merritt, Nicola, Alexandria, and Barnhartvale, Kamloops, British Columbia.

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A New Name for *Colletes albescens* Nosk. (Hymenoptera: Apoidea)

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In 1936, Noskiewicz proposed the name *C. albescens* for a new species of *Colletes* restricted to the Iberian Peninsula. The name is preoccupied by *albescens* Cresson, one of the common Nearctic members of the genus. I propose the name *Colletes noskiewiczi* (new name) for this species. A listing of the species in the index of the Noskiewicz work as *albiescens* is apparently a typographical error. The holotype and allotype of *noskiewiczi* (=*albescens* Nosk.) are in the collection of Dr. Dusmet-Maria in Madrid, Spain.

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A Note on the Presence of First-Stage Larvae of *Gasterophilus intestinalis* (Degeer) (Diptera: Gasterophilidae) in the Mouth of the Horse

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Wehr (1933a, b), Knipling (1934), Wells and Knipling (1938), and James (1947, pp. 92-98) stated that first-stage larvae of *Gasterophilus intestinalis* (Deg.) developed in the mucosa of the tongue, cheeks, and lips of the horse. Schroeder (1940) stated that first-stage larvae of *G. nasalis* (L.) established themselves in the spaces between the molar teeth below the gum line, where their accumulation caused considerable necrosis and resulted in the formation of pus pockets.

Studies conducted from the Lethbridge laboratory show that *G. intestinalis* as well as *G. nasalis* may be found in pus pockets between the teeth of horses. During the post-mortem examination of a number of horses from August to November, 1948, the majority of the larvae taken from between the teeth were of *G. intestinalis*. A total of 72 first-stage larvae, 3 in transition stages, and 16 early second-stage larvae of *G. intestinalis;* and 22 first-stage and 9 second-stage larvae of *G. nasalis*, were identified.

The maximum number of larvae taken from one pus pocket was 30. First-stage larvae of *G. intestinalis* were also taken from the mucosa of the tongue, and only occasionally from the cheeks and lips. *G. nasalis* was not identified from the cheeks.

The work was conducted at the plant of the Horse Co-operative Marketing Association, Swift Current, Saskatchewan, their laboratory facilities having been placed at the disposal of the Lethbridge staff.

The author acknowledges the assistance of Mr. A. R. Brooks, Systematic Entomology, Division of Entomology, Saskatoon, Saskatchewan, in the identification of the larvae.

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